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EX-ANTE ECONOMIC EVALUATION OF IMPROVED VERTISOL TECHNOLOGY: RESULTS FROM WHOLE-FARM MODELLING*

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Abstract

To increase and stabilise production in drylands, ICRISAT developed a watershed-based, soil- and water-management technology. While the technology is superior to traditional practices, its adoption is posing difficulties in some dryland situations.

This paper uses whole-farm modelling to simulate existing farming decisions, to determine the potential for technology adoption, and to evaluate the improved technology vis-a-vis traditional technology. It identifies existing and potential socio-economic constraints, and measures the potential impact of the improved technology on income, output, employment, and risk. The paper also analyses the demand for credit and the role of risk aversion.

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The paper emphasises the need for extension and development agencies to improve the farmers' entrepreneurial and managerial capabilities, expanding the supply of institutional credit, maintaining real wages through an effective wage policy, and ensuring reasonable prices for inputs and outputs.

Introduction

Unless the low productivity barrier in dryland agriculture is broken, the increasing food needs of developing countries such as India can no longer be met on a sustained basis. Drylands are characterised by low and uncertain rainfall, limited potential for irrigation, poor soil, and underdeveloped infrastructure, which lead to very low and highly unstable agricultural production. At present, less than 25% of the cultivated area in India is irrigated; even at the highest possible level of development of water resources, 60% of the area will continue to depend on rainfed agriculture. This underscores the importance of developing rainfed agriculture. Till recently, rainfed agriculture could hardly be improved and farmers achieved a great deal, given their traditional technologies. Improved technologies now offer the potential to considerably improve dryland farming.

Efforts have been underway and continue at various research institutes to develop appropriate technologies that increase and stabilise production in drylands. As a result of these earlier efforts, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has developed a watershed-based, improved soil- and water-management technology (ICRISAT, 1981). This technology has emerged from six years of research at ICRISAT Centre and several years of on-farm research. Successful results were achieved during the past two years in farmers' fields in a village representing deep Vertisol, relatively dependable rainfall regions of semi-arid tropical India (Ryan et al., 1982). The economic analyses carried out at various locations and at various stages of technology development have established the superiority of this technology over the traditional practices (Ryan and Sarin, 1981, Ryan et al., 1982, Sarin and Ryan, 1983). Even though spontaneous adoption of the improved technology has occurred in several places, the adoption of this technology package is posing difficulties in some dryland farming situations. Therefore, it is important to study the feasibility of transferring the improved technology to farmers' fields. The potential impact on agricultural development and the probable infrastructural requirements to facilitate such a transfer also need to be assessed.

In this paper, we evaluate the improved technology vis-a-vis existing traditional technology, with the specific objective of assessing if transfer of improved technology is feasible, and go on to identify the potential needs for infrastructural development. A whole-farm model was used initially to simulate the existing farming decisions, and subsequently to determine the potential for technology adoption. The analysis permits us to identify existing and potential socio-economic constraints and to measure potential impact on income, output, employment, and risk. We also analyse the demand for credit and the role of risk aversion.

The Technology

The improved technology involves better management of soil, water, and crops, on the basis of operational-scale watersheds of 1 to 15 ha. High-yielding varieties (HYV) of crops are sown on broadbeds, established between furrows, and treated with fertiliser. Most of the cultivation operations are carried out with an oxen-drawn wheeled tool carrier. The broadbeds and furrows are established with a graded slope of between 0.4 and 0.6%. This enables excess runoff, generally produced during heavy rainfall storms, to be guided slowly across the natural grades (usually 1.5 to 2%). In this way, rainfall infiltration may be increased and excess water removed with minimum erosion, stabilising soil moisture conditions.

The improved technology allows crops to be grown both in rainy season (kharif) as well as post-rainy season (rabi) on deep Vertisols in regions of SAT India with assured rainfall > 750 mm. In many of these regions the present practice is to keep the land fallow during the rainy season and cultivate it only during the post-rainy season on residual soil moisture.

Components of the improved technology are :

1. cultivating the land immediately after the previous post-rainy season crop, before the soil hardens;
2. improved drainage by smoothing land, installing field and community drainage channels, and using graded broadbeds and furrows;
3. dry seeding crops, before the monsoon;
4. using improved seeds and adequate amounts of fertiliser;
5. proper placement of seeds and fertiliser; and
6. improved plant protection.

Research results at ICRISAT Centre show that these technology options have generated profits that average Rs 3650/ha, as against Rs 500/ha from the traditional system (Ryan and Sarin, 1981). The improved technology yielded a return of 250% on increased operating costs and implies an increase in use of human labour by more than 250%. On-farm research experiments were carried out in 1981-82 and 1982-83 in Taddanpally village, in Medak district of Andhra Pradesh, to test the impressive performance of this technology. The village is representative of the rainy-season fallow, deep-Vertisol region with assured rainfall. In the first year, the experiment was carried out on a small watershed of 15.4 ha involving 14 farmers who chose nine cropping systems, which included some traditional crops[1].

Economic analysis of the first year of the Taddanpally experiment showed that the technology generates average gross profits of Rs 3060/ha, compared to the Rs 1625/ha from traditional systems, and gives a 244% return on the added expenditure confirming the experience at ICRISAT Centre (Ryan et al., 1982). The results were similar during the second year of the experiment and the analysis is reported at this seminar (Walker et al., 1983).

This study is based on the detailed input-output data collected for the agricultural year 1981-82 in Taddanpally on improved and traditional systems and on other resource-using activities. Data on resources and other constraints required for the programming model are derived from the comparable, rainy-season fallow, Sholapur region and from irrigated paddy areas of Mahbubnagar

region, where ICRISAT has been conducting village-level studies since 1975 (Binswanger and Ryan, 1979).

Whole-farm Modelling

As a part of ongoing research on evaluation of technology and policy options in SAT agriculture, a whole-farm modelling approach was developed (Ghodake and Hardaker, 1981) which, in essence, incorporates economic activities that the farmer can undertake to increase his level of welfare. A value for a specified objective function is optimised in the model through mathematical programming, to obtain levels of different activities that the farmer should undertake to overcome constraints and restrictions. Thus, the approach assigns imputed values for resources available to the farmer, with due regard for their actual availability and the demand for these resources. Aspects such as the risk involved in options, the farmers' attitude toward risk, and their subsistence needs, are also considered. Hence, the evaluation is performed within the framework of a defined farm-household model, taking into account interrelationships among all production processes through their dependence on common resources.

In the model it is assumed that the farmer maximises his expected utility, which is directly related to, and dependent on, money income and has a negative exponential functional form as follows:

$$U(Z) = 1 - e^{-\alpha z}$$

Where Z is an uncertain money income prospect and is absolute risk aversion coefficient, generally referred to as the Pratt coefficient (Pratt, 1964). When the income-generating activities such as cropping involve risk, a quadratic programming technique can be used to model the process and to generate an expected income-variance frontier. This frontier and the utility indifference curve, derived on the basis of the individual's risk aversion behaviour, permit determination of the optimal solution that maximises the expected utility of the decision maker. It can be shown that maximising the expected utility, represented by the above functional form, is equivalent to maximising the following quadratic risk programming formulation[2].

$$\text{Max } M = C'X - \frac{\alpha}{2} X'QX$$

$$\text{Subject to } AX \leq B$$

$$X \geq O$$

Where M = certainty equivalent income (to be maximised to optimise the farmer's expected utility);

- C = vector of activity net returns;
- X = vector of levels of activities;
- α = absolute risk aversion coefficient, determining the trade-off between expected income and variance;
- Q = variance-covariance matrix of activity net returns;
- A = matrix of input-output coefficients; and
- B = vector of levels of resources and constraints.

The above formulation assumes that net returns are normally distributed (Anderson et al., 1977). Walker and Subba Rao (1982) documented that the actual distribution of net returns for most improved and some traditional cropping systems in SAT India was sufficiently close to normal to justify this assumption. Absolute risk aversion coefficients (α's) were derived for different farm sizes from values of partial risk aversion coefficient (Hardaker and Ghodake, 1984) using the distributional results obtained by Binswanger (1980) in his large-scale study on measurement of risk attitudes of rural households in SAT India.

The above model was initially worked out, allowing only traditional technology to obtain optimal level of resource allocation under existing levels of resource and other constraints[3]. Some of the basic resources and other characteristics of average farms representing different farm-size classes in Taddanpally are given in Appendix Table 1. The potential borrowing limit from the institutional agencies has been set at Rs 700/ha. Therefore, the optimal solution would reflect production potential at this level of credit availability.

TABLE 1 :Shadow prices (Rs) of important constraints with traditional and improved technologies on indicated categories of farms in Taddanpally, Andhra Pradesh, 1981-82.

Constraining factor	Unit	Price (Rs)	Small		Medium		Large	
			Traditional	Improved	Traditional	Improved	Traditional	Improved
Land	ha	0	344	1553	29	938	487	1325
Irrigation	"	0	4442	2395	-	-	-	-
First season	"	0	1696	332	-	-	-	-
Second season								
Male labour								
Period 13 : 18th June-1st July	hr	0	-	-	-	-	-	0.52
" 20 : 24th Sept -7th Oct.	"	0	-	-	-	-	-	1.43
" 22 22nd Oct.-4th Nov.	"	0	-	-	-	-	-	1.43
" 23 5th Nov. -18th Nov.	"	0	-	-	-	-	0.86	-
Female labour								
Period 6 12th Mar - 25th Mar	hr	0	-	-	0.28	-	-	-
" 7 : 26th mar -8th Apr	"	0	-	-	-	-	0.25	-
" 9 . 23rd Apr -6th May	"	0	-	-	0.86	0.44	0.25	0.25
" 12 : 4th June-17th June	"	0	-	-	-	0.38	-	-
" 13 : 18th June-1st July	"	0	-	-	0.25	-	-	0.43
" 15 : 16th July-29th July	"	0	-	-	0.86	1.53	0.86	-
" 17 : 13th Aug -26th Aug	"	0	-	-	0.43	-	-	-
" 18 : 27th Aug-9th Sept	"	0	-	-	0.43	-		-
" 20 : 24th Sept-7th Oct	"	0	-	-	-	0.79		-
" 21 : 8th Oct-21st Oct	"	0	-	-	0.64	-	0.64	0.64
" 22 : 22nd Oct-4th Nov	"	0	-	-	0.25	0.86		-
" 23 : 5th Nov-18th Nov	"	0	-	-	-	-	-	0.84
" 26 : 17th Dec -31st Dec	"	0	-	-	0.25	0.25	-	-

Constraining factor	Unit	Price (Rs)	Small		Medium		Large	
			Traditional	Improved	Traditional	Improved	Traditional	Improved
Bullock labour								
Period 2: 15th Jan-28th Jan	pair hr	0	-	-	-	-	1.41	-
Hired male labour								
Period 23: 5th Nov - 18th Nov.	hr	0.86	-	-	-	-	-	1.58
Hired female labour								
Period 7: 26th Mar - 8th Apr	hr	0.25	-	-	6.41	-	-	-
" 10: 7th May - 20th May	"	0.25	-	2.66	-	5.72	-	5.40
" 13: 18th June - 1st July	"	0.43	-	-	-	15.43	-	-
" 14: 2nd July - 15th July	"	0.39	-	-	-	21.39	-	-
" 15: 16th July - 29th July	"	0.86	2.82	-	-	-	-	-
" 19: 10th Sept - 23rd Sept	"	0.43	-	-	1.07	1.12	5.13	2.58
" 21: 8th Oct - 21st Oct	"	0.64	-	-	-	0.19	-	-
" 23: 5th Nov - 18th Nov	"	0.84	7.86	2.25	0.16	9.32	4.34	-
Hired Bullock labour								
Period 6: 12th Mar - 25th Mar	Pair hr	1.25	-	-	-	-	7.53	-
Owned Cash	Rs.	-	0.36	1.10	0.13	0.78	0.13	0.84
Borrowing from formal agencies	Rs.	0.13	0.23	0.97	-	0.65	-	0.71
Borrowing from informal sources	Rs.	0.36	-	0.74	-	0.42	-	0.48
Milch animal	No.	-	929	330	790	875	815	580
Improved technology	ha	-	6836	-	4437	-	4487	-

Under the same level of resource and other constraints, improved technology options represented by various cropping systems were allowed into the model[4]. The programming solution then gave the level of improved technology activities and, consequently, the adoption potential and the corresponding levels of economic parameters. These results were used to perform a comparative economic analysis of the situation–with and without the improved technology. The two technologies were, therefore, not directly compared; rather the effects of including the improved technology were evaluated with the traditional technology as a point of reference. The impact of some important variables-such as credit and risk aversion-on the performance of these technologies were evaluated by varying the parameters within their valid ranges.

Results

Potential for Technology Adoption

Results with and without the improved technology for various categories of farms are given in Table 1. Under the existing resource endowments and other constraints, the adoption potential for the improved technology varies with the size of the farm. Small farms adopt the improved technology on 90% of the land they cultivate, medium farms do so on 60%, and large farms on 77%. This difference is from variation in the resource base, particularly in female labour availability, between these farms. Shadow prices (Table 1) indicate that female labour is generally a strong constraint during many of the periods on medium farms. Shadow prices are much higher with the improved technology than with the traditional technology. This is because of relative scarcity of family female labour on medium farms when compared to small farms, and also their more limited access to hired female labour than large farms. Generally, enough family female labour on small farms and adequate access to hired female labour by large farms allow these two categories of farms to practise the improved technology on a larger share of their cultivated land. The high level of adoption of the improved technology by small farms may partly be because there is no irrigation on these farms.

A cursory look at shadow prices (Table 1) allows us to identif the constraints, their intensity, and any shift in them from the improved technology. With the traditional technology, human labour–especially female–is a constraint during the second fortnight of July mainly because of preparatory tillage, weeding in mung bean, and transplanting of paddy. More constraining periods are the second and third weeks of September mainly because of land preparation for post-rainy crops, weeding in chillies, and intercultivation and weeding in paddy. This is followed by a longer period–beginning the second week of October until the third week of November-when farmers are busy in harvesting and threshing of paddy, sowing of post-rainy-season crops, and weeding and intercultivation in already emerged post-rainy-season crops.

The peak labour demand period observed under traditional technology seems to require both forward and backward extensions with the adoption of improved technology. The first constraining period starts with the first week of June and continues till the end of July; during this period important operations with the improved technology are sowing, resowing and gap filling in rainy season crops, land preparation, weeding and fertiliser application, spraying, and thinning. Transplanting of paddy is another important activity during this period. This is followed by a peak period from the second week of September to mid-November, which is also common with the traditional technology. With the improved technology, during this period, farmers need to perform operations such as land preparation for post-rainy season crops, harvesting and threshing of rainy season such as *HYV* sorghum, mung bean, and maize, and sowing of post-rainy season crops such as safflower and chickpea. Another major activity during this period is the harvesting and threshing of paddy. This peak period could extend till the end of December because of intercultivation operations in post-rainy season crops.

Irrigation seems to be a constraint only on small farms. Interestingly, irrigation is not a constraint on medium and large farms with other resources and constraints at their current levels. To that extent, irrigation is not fully utilised either under the traditional technology or with the improved technology. In spite of a provision for maximum borrowing (Rs 700/ha), credit proved to be a constraint with the improved technology while it is sufficient with the traditional technology, except on small farms. The shadow price of the

improved technology per unit of operated land is the highest on small farms, followed by medium and then by large farms. This indicates that the improved technology can potentially offer greater benefit to smaller farms.

The improved technology permits crops to be grown during the rainy season, thereby increasing the effective supply of land through land augmentation. Such augmentation is an important contribution that this technology makes in land-scarce economies such as India. Land-use intensity, which is the summation of seasonal cropping intensities over the two seasons, goes up on these farms by 50 to 80% (Table 2).

Impact on Income, Cost and Risk

With the introduction of the improved technology, gross income rises by 70 to 90% on these farms, net income by 65 to 85%, and variable costs by 70 to 110%. In terms of relative increases in gross, net, or expected incomes, small farms receive the highest benefit from the improved technology.

When these farms are given access to improved technology, there is a drastic reduction in relative risk (CV) that they would have to face. This in turn results in a remarkable decrease in the proportionate risk premium that these farmers would have to pay to avoid loss in income. Here, too, the improved technology demonstrates its small-farm orientation. However, these results cannot be used to generalise about scale economies, because these farms are significantly different in terms of irrigation and other non-land resources. Nevertheless, existing farming alternatives and the resource base they command allow small farms to benefit the most from improved technology.

Land Allocation

Detailed allocation of land to important cropping systems so as to optimise output is presented in Appendix Table 2. With the traditional technology, local sorghum and its intercrops with either pigeonpea or safflower dominate the farmers' fields, with a small area under mung bean as a sequential crop. With the improved

Table 2: Adoption potential for improved technology and its impact on income, cost and risk on indicated categories of farms at Taddanpally, Andhra Pradesh, 1981-82.

Particulars	Small			Medium			Large		
	Only traditional technology	With improved technology	Percent Increase (+) or decrease (-)	Only traditional technology	With improved technology	Percent Increase (+) or decrease (-)	Only traditional technology	With improved technology	Percent Increase (+) decrease (-)
Land under traditional technology[1] (%)	100	10	-90	111	53	-52	105	30	-71
Land under improved technology (%)	-	90	-	-	59	-	-	77	-
Land-use intensity[2] (%)	109	197	80	115	174	51	124	189	52
Gross income (Rs)	4090	7753	90	8274	14125	71	19347	32270	67
Variable cost[3] (Rs)	799	1679	110	2138	3844	80	4907	8449	72
Net income (Rs)	3291	6074	85	6136	10281	68	14440	23821	65
Expected income[4] (Rs)	224	2916	1202	2487	6455	160	9478	18961	100
Coefficient of variation of expected income (%)	383	36	-91	50	22	-56	28	17	-39
Risk premium[5] (%)	221	25	-89	30	16	-47	15	11	-27

1. The percent land allocation is computed by using operated land as base.
2. Land-use intensity has been obtained by adding seasonal cropping intensities over the two seasons.
3. Variable expenditure is on items such as seeds, fertilizer, farmyard manure, pesticides, hired bullock labour, hired human labour, Tropicultor hiring, and other inputs.
4. Expected income is computed by subtracting variable expenditure and value of minimum home consumption from gross income.
5. Risk premium is the difference between expected income and certainty equivalent income. The certainty equivalent income has been estimated by considering riskiness of the technology (variance) and attitude of the farmer towards risk (absolute risk aversion coefficient).

Table 3 :Impact of improved technology on employment, borrowing, fertiliser consumption, and output on different categories of farms in Taddanpally, Andhra Pradesh, 1981-82.

Particulars	Small			Medium			Large		
	Only traditional technology	With improved technology	Percent Increase (+) or decrease (-)	Only traditional technology	With improved technology	Percent Increase (+) or decrease (-)	Only traditional technology	With improved technology	Percent Increase (+) decrease (-)
Employment									
Male (hr)	611	769	26	1509	1792	19	3150	3678	17
	(68)[1]	(83)		(60)	(58)		(61)	(63)	
Female (hr)	607	717	18	1873	2046	9	4009	4489	12
		(116)	(116)		(79)	(73)		(94)	(87)
Bullock (pair hr)	149	127	-15	465	440	-5	1055	919	-13
		(118)	(95)		(94)	(73)		(75)	[illegible]
Tropicultor[2] (hr)	0	42	-	0	76	-	0	170	-
Borrowing[3] (Rs)	1336	1550	16	1780	2900	63	3941	5580	[illegible]
Fertiliser consumption (Rs)	37	712	1824	436	1414	224	[illegible]	3587	[illegible]
Output (kg)									
Local sorghum	580	300	-48	1040	610	-41	2540	[illegible]	[illegible]
Paddy	0	0	0	2400	2400	0	[illegible]	[illegible]	1
Pulses	50	390	680	0	670		210	1520	624
Maize	0	250	-	0	760		0	[illegible]	-
Pigeonpea	30	300	900	50	500	900	90	1280	1322
HYV sorghum	0	1490	-	0	1760	-	0	[illegible]	
Fodder	1600	7300	356	410	11400	[illegible]	10200	[illegible]	[illegible]

1 Figures in parentheses are coefficients of variation of fortnightly labour use
2 Indicates that percentage has not been worked out because of zero denominator value.
3 Includes borrowing from both institutional and informal sources.

technology, the HYV sorghum and pigeonpea intercrop occupies a major area on small and medium farms and a substantial area on large farms. Mung bean as a sequential crop, included by the cooperating farmers on watershed plots to try their traditional cropping patterns, occupied 21 to 33% of operated land on these farms. This shows that even the traditional cropping systems responded well to the improved soil and water-management practices, and they have the potential to compete with improved cropping systems such as HYV sorghum/ pigeonpea. In contrast, maize/pigeonpea and maize-chickpea, which were the most promising cropping systems at ICRISAT Centre, were sown only on 7 to 21% of operated land. Chillies and maize-safflower did not feature in the optimal solution.

Inputs and Outputs

The impact of the improved technology on employment, borrowing, fertiliser consumption, and output are shown in Table 3. The overall level of labour input goes up substantially with the use of improved technology on these farms, with a higher proportionate increase in male labour.

As the supply of female labour is restricted during a few critical periods, the employment potential for women under this technology is higher than what Table 3 indicates. Only draft power input declines by 5 to 15% mainly because of the wheeled tool carrier, which increases bullock labour efficiency by a factor of 2.15 over the traditional implements (Bansal and Srivastava, 1981). The demand for bullock power may increase with the adoption of improved technology, which requires that additional inputs and outputs be transported. Values of coefficient of variation (CVs) in fortnightly labour use (parenthetical figures in Table 3), show a general pattern of decline with the improved technology on these farms, except for male labour on small and large farms. The improved technology helps not only in increasing employment but also in providing more stable employment–which is essential to remove any disguised seasonal employment, more prevalent in dryland agriculture–and in providing jobs to people on a more continuous basis. There is 16 to 63% increase in the utilisation of borrowing capacity. Fertiliser consumption goes up by about 1800% on small farms, 200% on medium farms, and 300% on large farms. This suggests the magnitude of additional fertiliser supplies required, and the potential backward linkages with other input markets.

Table 3 also shows quantum jumps in the output of most crops that are directly or indirectly affected by the improved technology. The output of local sorghum drops by about 40 to 50%. This drop is more than compensated by manifold increases in outputs of other crops especially other pulses, pigeonpea, HYV sorghum, and maize. Fodder production goes up by 150-350%, indicating the potential of this technology to support livestock, which is an important source of draft power and milk in the drylands. If one adjusts for fodder quality differences, then the fodder value would rise by 32 to 143%.

Rate of Returns and Factor Proportions

More relevant and directly comparable economic parameters are presented in Table 4. Rates of return on variable expenditure, estimated for net profits with the traditional technology are 117% on small farms, 25% on medium farms, and 45% on large farms; the corresponding figures for the improved technology are 216% for small farms, 113% for medium farms, and 129% for large farms. This parameter is directly relevant to weighing the relative profitability of short-term cash input, which is of immediate relevance to the adoption decision of the farmer. Rates of return on total cost, which includes both variable and fixed costs, are substantially higher with the improved technology than with the traditional technology–by 200% for small farms, 600% for medium farms, and 300% for large farms. The technology offers attractive rates of return on additional costs. These rates on additional variable expenditure are 270% on medium farms, 290% on large farms, and 350% on small farms. Rates of return on added costs are 190% on medium farms, 200% on large farms, and 240% on small farms. Thus, the overall performance of the technology analysed under the whole-farm situation supports the results obtained earlier by using partial budgeting (Ryan et al., 1982, Ryan and Sarin, 1981).

Net revenue per unit of land, labour, and variable expenditure all increase considerably to substantially on these farms. Net revenue per unit of land, which is a scarce resource, increases by 73 to 94%; net revenue per unit of labour, which is relatively abundant, goes up

Table 4 :Changes in rate of return, revenue per unit of inputs, and factor proportions with improved technology in Taddanpally, Andhra Pradesh, 1981-82.

Items	Small		Medium		Large	
	Only traditional technology	With improved technology	Only traditional technology	With improved technology	Only traditional technology	With improved technology
Rate of return[1] on variable expenditure (%)	117	216 (349)[2]	25	113 (266)[2]	45	129 (294)[2]
Rate of return on total Cost (%)	40	93 (238)[3]	8	46 (189)[3]	16	54 (203)[3]
Net revenue/land (Rs/ha)	2025	3937 (94)[4]	1719	3040 (77)[4]	1969	3419 (73)[4]
Net revenue/labour (Rs/ha)	2.54	4.05 (59)[4]	1.70	2.65 (56)[4]	1.89	2.88 (52)[4]
Net revenue/variable expenditure (Rs/hr)	3.13	3.48 (11)[4]	2.27	2.56 (13)[4]	2.33	2.69 (15)[4]
Operated land/labour (ha/1000 hr)	1.26	1.03	0.99	0.87	0.96	0.84
Nonland assets[5]/labour (Rs/hr)	1.34	1.95	3.62	3.68	4.52	4.58
Variable expenditure/labour (Rs/hr)	0.81	1.16	0.75	1.03	0.81	1.07

1. The rate of return is estimated for net profit which is gross revenue minus total cost. Total cost includes variable expenditure, rental value of land, wages, and value of fixed capital in farm production. Variable expenditure here includes imputed value of owned bullock labour, in addition to items mentioned in Table 1, footnote 3, while it excludes wages of hired-in human labour and rental value of Tropicultor.
2. These figures indicate % rate of return on additional variable expenditure with improved technology.
3. These figures indicate % rate of return on added total costs with improved technology.
4. These figures indicate % increase over the traditional technology.
5. Nonland assets include farm machinery, implements, farm buildings, milch and other animals, owned cash, and irrigation infrastructure. With the improved technology, the wheeled tool carrier is included under assets.

by 52 to 59%; net revenue per unit of variable expenditure increases by modest figures of 11 to 15%. All these relative changes indicate a desirable feature of the technology: increasing returns to relatively scarce factors.

The bottom three rows in Table 4 present factor proportions with and without the improved technology. The ratio of land to labour used declined consistently on all these farms, showing a desirable change in the direction of more employment per unit of land, which benefits labour. There is a rising trend in the ratio of non-land assets to labour use. With the improved technology, the wheeled tool carrier raises the non-land assets and offsets the effect of increased labour input. This results in an overall increase in the non-land assets/labour ratio on all these farms. But the rise is more pronounced on small farms because these are non-irrigated and, therefore, have low initial level of nonland assets. The ratio of variable expenditure to labour rises with the improved technology, again consistently, on these farms. This means that the improved technology alters, to some extent, the capital-labour ratio in favour of capital.[5]

Village-level Impacts

The village-level impacts of the improved technology on various parameters are shown in Tabl 5. The impact values have been computed by giving weights of proportionate cultivator households in Taddanpally village to corresponding values on respective farms. The values are expressed on a per average-farm basis as well as on a per hectare basis.

On an average farm of 3 ha, the improved technology would be adopted on 74% of its operated land, resulting in 59% increase in land-use intensity. That would increase gross income by 74%, net income by 71%, male labour input by 20%, and female labour input by 12%. There would be 56% decline in risk, and a 47% decline in risk premium. The variable cash required would be 83% higher for improved technology than for traditional technology; bullock labour input would decline by 10%. The demand for fertiliser would go up by 360%. Borrowing would increase by about 40% and would still be a constraint to the adoption of improved technology.

Table 5 :Average village-level impact[1] of improved technology on income, cost, employment, borrowing, fertiliser consumption, and output in Taddanpally, Andhra Pradesh, 1981-82.

Items	Only traditional technology	With improved technology	Increase (+) or decrease (-)	Percent change
Land under improved technology	-	74	74	-
Land use intensity (%)	117	186	69	59
Gross income (Rs)	7912 (2652)[2]	13778 (4619)	5867 (1967)	74
Variable cost (Rs)	1898 (636)	3477 (1165)	1579 (529)	83
Net income (Rs)	6014 (2016)	10302 (3454)	4288 (1438)	71
Coefficient of variation of expected income (%)	52	23	-29	-56
Risk premium	30	16	-14	-47
Male labour (hr)	1314 (440)	1572 (527)	258 (87)	20
Female labour (hr)	1569 (526)	1759 (590)	190 (64)	12
Bullock labour (pair hr)	398 (134)	357 (120)	-41 (-14)	-10
Wheeled tool carrier (hr)	0	74 (25)	74 (25)	-3
Borrowing (Rs)	1900 (637)	2676 (897)	776 (260)	41
Fertiliser consumption (Rs)	307 (103)	1404 (471)	1097 (368)	357
Output (Kg)				
Local sorghum	1050 (350)	580 (190)	-470 (-160)	-45
Paddy	1720 (580)	1720 (580)	0 (0)	0
Pulses	60 (20)	660 (220)	600 (200)	1000
Maize	0 (0)	830 (280)	830 (280)	-
Pigeonpea	50 (20)	520 (180)	480 (160)	960
HYV sorghum	0 (0)	1870 (630)	1870 (620)	-
Fodder	380 (1270)	11530 (3870)	773 (258)	203

1. Village-level impact is worked out by using weights of proportionate cultivator households in each farm-size category, and is expressed as values on an average farm of 3 ha.
2. Figures in parentheses are per hectare values.
3. When denominator values are zero, the % change has not been computed.

With the improved technology, except for about 45% decline in the output of local sorghum, all other outputs would rise. On an average, the aggregate food production would increase by a factor of 2.14, and fodder production would go up by a factor of 3. If one accounts for value differences owing to type and quality of output, then the overall increase in the value of output would be by 178%.

Demand for Credit and Repayment Potential

The shadow prices in Table 1 show that in spite of borrowing upto Rs 700/ha, credit has been an important constraint in realising the potential benefits of improved technology. In this section, we vary the availability of institutional credit to gauge its impact on the performance of the traditional technology vis-a-vis the improved technology. We attempt particularly to assess the demand for credit and the potential of borrowers to repay it. We have run the model with five different levels of credit availability. One is Rs 150/ha, which is close to the ad hoc scale of Rs 125/ha as adopted by the Working Group on Cooperative Credit for the Fifth Five-Year Plan (1974-79). The second level of Rs 300/ha approximates the all-India average debt of Rs 324/ha of owned land. The third level of Rs 700/ha is equivalent to the average amount of loan provided per hectare of watershed in Taddanpally by the Andhra Pradesh Department of Agriculture.[6] No credit and unrestricted credit are also included.

Results at these levels of credit availability are presented in Table 6. The table shows that with the traditional technology, credit up to Rs 300/ha on small farms results in infeasible solutions, which means the credit is insufficient to meet current expenses of the farm. Obviously, the repayment capacity is zero. In this situation, the farmer would go into debt unless he manages to meet some of his credit needs through informal sources. With the improved technology, even a credit of Rs 150/ha is enough to keep the farmer in business. This indicates that the improved technology increases the feasibility of credit use to such an extent that the farmer is enabled to repay 20% of his loan. Higher amounts of credit are, however, needed to reap the full potential benefit of this technology.

Table 6: Potential demand for and repayment of institutional credit with traditional and improved technologies in Taddanpally, Andhra Pradesh, 1981-82.

Farm size	Credit level (Rs/farm)	Traditional technology: Credit utilised[1] (Rs/farm)	Traditional technology: Shadow price of credit (Rs)	Traditional technology: Marginal rate of net revenue increase	Traditional technology: Repayment potential[2] (%)	With improved technology: Credit utilised[1] (Rs/farm)	With improved technology: Shadow price of credit (Rs)	With improved technology: Marginal rate of net revenue increase	With improved technology: Improved technology adoption (%)	With improved technology: Repayment potential[2] (%)
Small	0	**[3]	**	**	-	**	**	**	**	-
	150	**	**	**	0	200	3.42	-	30	20
	300	**	**	**	0	500	2.53	1.93	59	100
	700	1100	0.23	-	20	1100	0.97	2.41	90	100
	No limit	1360	0	0.12	33	1840	0	0.27	91	100
		(890)[4]				(1200)				
Medium	0	0	4.69	-	-	0	4.26	-	17	-
	150	500	0.87	1.71	100	500	3.82	3.75	33	100
	300	1000	0.26	0.46	100	1000	2.55	3.54	54	100
	700	1780	0	0.21	100	2300	0.65	1.78	75	100
	No limit	1780	0	0.21	100	3130	0	0.21	77	100
		(530)				(940)				
Large	0	0	2.97	-	-	0	4.14	-	16	-
	150	1000	1.17	1.73	100	1000	3.59	3.70	38	100
	300	2100	0.64	0.93	100	2100	2.83	3.00	55	100
	700	3940	0	0.35	100	4800	0.71	2.00	81	100
	No limit	3940	0	0.35	100	6760	0	0.34	80	100
		(570)				(980)				

1. This is the institutional credit requirement indicated by optimal programming solution.
2. Repayment potential is computed by subtracting variable expenses and minimum consumption expenses from total income
3. Asterisks indicate infeasible programming solution and hence infeasible farm business, meaning the farmer would be in debt.
4. Figures in parentheses are potential credit needs (Rs/ha) from formal sources.

It is clear that credit will play an important role in adoption of the improved technology. If institutional credit is not available, the adoption level is nil on small farms, 17% on medium farms, and 16% on large farms. When credits amounting to Rs 1840/ha. are extended to small farms, the adoption level goes up to 91%; if medium farms are extended credits amounting to Rs. 3130/ha the adoption level goes up to 77%; and if large farms are extended credits amounting to Rs 6760/ha, 80% of them would adopt improved technology.

With the improved technology, credit needed from institutional sources is Rs 1200/ha on small farms, Rs 940/ha on medium farms, and Rs 980/ha on large farms. If assessed demand for credit is compared with the all-India average of Rs 324/ha, there seems to be a wide gap in the availability of institutional credit. Even the figure of Rs 700/ha adopted by the Andhra Pradesh Department of Agriculture is much below the potential credit need.[7]

At comparable levels of credit, the marginal rate of net revenue increases with the improved technology and is much higher than that obtained with the traditional technology. So are shadow prices. Only when the credit level is zero is there an infeasible solution for small farms. On small farms the repayment potential with the improved technology is 20% at the credit level of Rs 150/ha, which goes up to 100% at Rs 300/ha. With the traditional technology even when unlimited credit is available (Rs 890/ha), the repayment potential is just 33% on small farms. For medium and large farms, both these technologies show 100% repayment capacity. This suggests that the improved technology increases the repayment potential of the farmer, which would- albeit indirectly help financial institutions to meet the credit needs of farmers.

Risk Aversion and Technology Choice

The influence of risk aversion on the adoption of the improved technology is evaluated in this section. Risk aversion (absolute risk aversion coefficient) varied in the range of minus one SD (low) to plus one SD (high) for each farm. This range corresponds to the distributional results of risk attitude measurements (Binswanger, 1980). Risk is measured in terms of the coefficient of variation of farm income. The measure of income used here is returns to family-owned resources and includes both certain and uncertain income. The risk premium is defined as expected income minus certainty equivalent income, and is expressed as the percentage of expected income.

The results show that at each level of risk aversion, the improved technology exhibits substantially lower level of risk (CVs) compared to the traditional technology on all the three categories of farms (Table 7). With increasing risk aversion, risk is reduced with both these technologies, traditional technology on small farms being an exception. The level of risk on small farms with the traditional technology increases, while the risk seems to decrease with improved technology. This is perhaps because these farms, in the process of meeting their minimum subsistence needs, do not have sufficient choice of alternatives to reduce risk by more than the reduction in income. Variation in risk aversion does not affect the adoption potential for the improved technology.

At each level of risk aversion, the relative amount of risk premium that these farmers would face is much lower with the improved technology than with the traditional technology. As expected, the higher the level of risk aversion, the higher is the proportionate risk premium. The proportionate risk premium, however, goes up much higher with the traditional technology than with the improved technology. This reinforces the risk-reducing characteristic of the improved technology, and suggests that farmers' risk aversion is not a constraint to the adoption of improved technology.

Conclusion

Results from whole-farm modelling, based on data from on-farm verification trials, show that the improved (soil- and water-management) technology contributes significantly to growth and stability of production in assured-rainfall, deep-Vertisol regions of dryland areas. The impressive performance of this technology, however, needs to be further tested on locations with varying soil and moisture conditions in these regions. Information on the potential of the improved technology will have to be obtained from more location-specific trials, conducted with less intensive supervision by scientists and technicians.

Table 7 : Impact of risk aversion behaviour on choice of risk level and on risk premium with traditional and improved technologies on different categories of farms in Taddanpally, Andhra Pradesh, 1981-82.

Risk aversion level[1]	Small		Medium		Large	
	Only traditional technology	With improved technology	Only traditional technology	With improved technology	Only traditional technology	With improved technology
	Coefficient of variation of expected income					
Neutral	224	51	69	36	40	26
Low	224	48	68	26	40	23
Medium	230	40	55	22	37	19
High	384	36	50	19	28	15
	Risk premium (%) of expected income					
Neutral	0	0	0	0	0	0
Low	50	15	20	7	10	6
Medium	89	18	22	10	16	8
High	221	25	30	14	15	10

1. Absolute risk aversion coefficients corresponding to different levels of risk aversion are:

Level	Small	Medium	Large
Low	0.0003664	0.0002718	0.0001129
Medium	0.0007021	0.0005207	0.0002162
High	0.001345	0.0009973	0.0004141

The normative nature of results, especially because of the limitation of programming models in simulating fully the behaviour of the farmer, may constrain their applicability to larger areas. Results and implications may be particularly sensitive to regional variation in alternative employment and production opportunities, and to changes in the resource base. Whole-farm modelling is intensive in its demand for data, particularly the time-series and cross-sectional informaion representing probable states of nature over a wide spectrum of farms. Hence, these results should be interpreted with caution beause the performance of the improved technology is based on one cropping year. Besides, the present models are based on single-period decisions and, therefore, do not allow dynamic adjustments in saving, investment, consumption, and in changes from later, second-round effects.

Nevertheless, the evaluation strongly supports the positive aspects of this technology. The assessment also derives implications for appropriate institutional changes to fully tap the technology's potential. The study emphasises the need for extension and other development agencies to improve the farmers' entrepreneurial and managerial capabilities, expand the supply of institutional credit, maintain real wages through an effective wage policy, and ensure reasonable prices for inputs and outputs.

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Footnotes

1. Under their traditional practice, these farmers grow post-rainy-season local sorghum-chillies-mung bean, local sorghum/pigeonpea, local sorghum/safflower intercrop, and local and HYVs of paddy on wetlands. Under the improved technolgy, the cooperating farmers grew HYV sorghum/pigeonpea, maize/pigeonpea, maize-safflower, maize-chickpea, and some crops taken on traditional pattern such as mung bean-sorghum, mung bean-safflower, mung bean-sorghum-chickpea, and mung bean-chillies.

2. Markowitz (1956) used quadratic formulation to generate efficient E-V frontier while Freund (1956) used it for accounting risk into a programming model. Bond and Wonder (1980) used the risk premium as a measure of risk attitude and derived risk coefficients for use in risk programming models.

3. A programming package called MINOS (a Modular In-core Nonlinear Optimisation System), developed at the Systems Optimisation Laboratory, Department of Operations Research at Stanford University, (Murtagh and Saunders, 1977) and available on ICRISAT's VAX/11-780 computer, was used to solve the problems.

4. The full programming model used had 168 activities, which broadly included crops, labour hiring-in, labour transfer, buying of food and other items, milch animals, selling of farm output, borrowing, and consumption. There were 269 rows specifying constraints and restrictions, which included land, irrigation, family labour, labour hiring-in, consumption of food items, maximum area under crops, cash availability, borrowing limit, buying of food items, and many other tie, transfer, and accounting restrictions. The variance-covariance matrix of net returns for activities which involve risk was computed separately. For the improved technology crops, cross-sectional data across plots were used; for the traditional crops, time-series as well as cross-sectional data were used from comparable regions.

5. For some speculation on the possible direction of changes in important prices and relative factor shares, see Ghodake and Kshirsagar (1985).

6. For discussion on institutional credit supply, see Ryan et al. (1982), and Bhende (1983).

7. The variation in credit needs, across farm sizes, is rational, as a part of credit is used for consumption purposes by small farmers, while some part is used in supporting complementary activities such as livestock. The whole-farm models account for such requirements.

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APPENDIX TABLE 1: **Important features of average farms representing different categories of farms in Taddanpally, Andhra Pradesh.**

Feature	Farm size category		
	small	medium	large
Operated land (ha)	1.53	3.34	6.88
Irrigated land (ha)	0	0.54	1.62
Net Irrigated land (%)	0	16.2	23.5
Male workers (No./10 ha of operated land)	11	6	4
Female workers (No./10 ha of operated land)	9	4	6.5
Bullocks (pairs/10 ha of operated land)	2.2	4.4	2.4
Owned cash[1] (Rs/farm)	0	200	500
Borrowing limit from Institutional agencies[2] (Rs/farm)	1100	2300	4800
Borrowing potential from Informal sources[3] (Rs/farm)	450	600	1000
Risk attitude (absolute risk aversion coefficient[4])	0.001345	0.0009973	0.0004141
Farms represented (%)	51	33	16
Cultivated land represented (%)	21	40	39

1. The amount that the farmer would be able to save from the previous agricultural year and that would be available for spending in farm production.
2. This is a short-term crop loan given by the agricultural bank, nationalised bank, or a village cooperative. A maximum of Rs 700/ha for dryland crops, which is the potential highest, has been mentioned here.
3. Informal sources include moneylenders, businessmen, relatives, and friends.
4. Derived from values of partial risk aversion coefficients and distributional results obtained by Binswanger (1980).

APPENDIX TABLE 2: Allocation of land (%)[1] to important cropping systems with traditional and improved technologies on indicated categories of farms in Taddanpally, Andhra Pradesh. (Results from quadratic risk programming models.)

Technology/cropping system	Small: Only traditional technology	Small: With improved technology	Medium: Only traditional technology	Medium: With improved technology	Large: Only traditional technology	Large: With improved technology
Traditional						
Irrigated paddy	92.0	10.0	106.2	52.6	101.7	30.4
Local sorghum/pigeonpea or safflower	0	0	21.4	21.4	15.3	15.3
Mung bean-local sorghum	83.6	3.9	84.8	31.2	77.6	15.1
	9.2	6.1	0	0	8.8	0
Improved						
HYV sorghum/pigeonpea	-	90.1	-	58.7	-	74.6
Mung bean sequential crops taken on traditional pattern[2]	-	50.1	-	26.5	-	23.9
Chillies or maize-safflower	-	32.8	-	20.8	-	29.8
	-	0	-	0	-	0
Maize/pigeonpea or maize-chickpea[3]	-	7.2	-	11.4	-	20.9

1. The per cent land allocation is computed by using operated land as base.
2. Crops taken after mung bean by the cooperating farms were local sorghum-chillies-safflower and chickpea/sorghum.
3. Most promising cropping system observed at ICRISAT Centre (Ryan and Sarin, 1981).

SEVEN

ANALYSIS OF CONSTRAINTS IN TRANSFER OF DRYLAND TECHNOLOGY: AN OPERATIONAL RESEARCH EXPERIENCE*

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Abstract

To critically evaluate the improved technology developed by the pilot development projects under farmers' management conditions, the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) conducted operational research at Bangalore, Hoshiarpur, Hyderabad, Indore, and Ranchi. While a third of the research recommendations were found to be unsuitable, half the remaining practices were highly profitable.

Adoption of the remaining practices, which showed an additional return of 100 to 200% on investment, was affected by institutional and operational constraints. These were: inadequate labour/bullocks, default in the repayment of loans, complex procedures for obtaining credit, improved seed not being available in time,

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